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THE PREPARATION OF A GEOLOGIC MAP.

THE following paper is a discussion of certain factors influencing the quality of a geologic map; and an attempt has been made to formulate the conditions which must be fulfilled before a map can be considered satisfactory. Two important branches of the subject, however, are not treated: the drafting and the process work. The quality of both is closely dependent on the amount of money available for the preparation of any particular map, and therefore neither can be discussed in a general way. Disregarding these more purely mechanical factors, the value of a geologic map depends upon the accuracy and the precision of the field work; on the completeness with which certain data, both geologic and geographic, are presented on the maps; and on the care with which scale, colors, conventions, etc., are chosen so as to give the best results.

A section might, perhaps, have been devoted to a consideration of the ethical questions involved in the preparation and publication of a geologic map. The writer has, indeed, discussed certain of these points, but from the point of view of expediency rather than of abstract justice. The ethical code for the cartographer is simple; he should give due credit for work done by others; and he should frankly acknowledge doubt or ignorance. The first canon requires that both the geologic and geographic data should be properly credited; the second, that geologically unknown areas should be left blank, that doubtful boundaries should be distinguished from those accurately traced; and that, if possible, the location of actual outcrops should be indicated.

I. ACCURACY AND PRECISION OF FIELD WORK.

The map should show geologic boundaries as precisely as the geographic and topographic accuracy of the base will permit.

When, as frequently occurs, a geologic map falls below this

grade of accuracy, the fault is generally in the field work, and not in the map-drafting. Many geologists fail to realize in practice, though they may admit in theory, that geologic mapping on an atlas sheet is very different from mapping on a post-route map. It might seem hardly necessary to say that the geologic boundaries, when a contoured base is used, should be accurately fitted to the topography; but unfortunately evident violations of this rule are frequent. In one very recent instance a map, whose mechanical execution is admirable, is accompanied by structure sections which show that the geologic boundaries on the contoured map are in physically impossible positions.

Throughout much the greater part of the United States geologic mapping must be carried on in areas which have not as yet been mapped with any approach to accuracy. County, land-office, or post-route maps will be the only bases obtainable. In any inhabited area, roads are surveyed and mapped with tolerable accuracy long before any attempt is made to show drainage or relief. For this reason, in geologic mapping in a base known to be geographically inaccurate, boundaries and outcrops should be, when possible, referenced with respect to roads and road intersections, and not with regard to natural features. If thus referenced, these boundaries may be transferred to another base at any time, without necessitating the revision of the field work.

The accuracy of the field work is not a matter which interests the cartographer so much as its precision. If the field geologist has erred in determining the age or general relations of a certain formation, the cartographer cannot question the determination. He has, however, a right to ask that boundaries be traced and locations made with a certain degree of precision, a degree which will vary with the character of the base map used; and that the various elements of the manuscript map agree *inter se* (e. g., that the areal mapping is not contradicted by the structure sections).

II. REQUISITE GEOLOGIC DATA.

Title.—The title of the map, omission of which is rarely permissible, should explain the character of the mapping (geologic,

outcrop, reconnaissance, detailed, etc.), and should also describe the area covered by the geologic coloring. As to wording, the title should be as concise as possible, and grammatically correct. such expressions as "Geologic map of the — river," or "Geologic map of the — limestone," should be avoided. It is frequently necessary to publish maps of areas which for some reason cannot be readily located or described in words, so that the title (unless made unreasonably long) cannot be made entirely satisfactory in regard to its geographic precision. In such cases at least one meridian of longitude and one parallel of latitude should be introduced and properly numbered, to serve as an aid in locating the area mapped.

Author and date.—The name of the geologist or compiler should be given on the map, together with the date. So far as the latter is concerned, for most purposes the year will be sufficient; occasionally a more precise statement will be advantageous. This date should in every case be the date of completion of the manuscript map; its date of publication will be fixed by other evidence.

Acknowledgments.—In the case of a compilation, if space be available, credit should be given on the map to the various geologists whose partial maps were utilized. If space is not available on the map itself, reference should be made to the publication in which these acknowledgments are made. Remissness in this respect, whether intentional or not, is unpardonable. Plate I of Monograph V, United States Geological Survey, (*Copper Bearing Rocks of Lake Superior*), is particularly detailed in its acknowledgments, despite its comparatively small size.

Legend.—The amount of detailed information to be given in the legend is governed by two considerations. The first is, of course, the amount of space available on the map. The second, on which sufficient stress is rarely laid, is the liability of the map to be separated from the text. Every convention used on the map must be explained in the legend; but the extent to which this explanation should be carried depends largely on the form in which the map is published. A map issued in a roll or pocket

will almost invariably become separated from the volume or paper which it is supposed to accompany; and the legend of a map published in that shape should accordingly be as detailed as possible. A map inserted as a plate is somewhat less likely to be used separately and the legend may be less detailed; while a map set in the text cannot well be separated from it and its legend may therefore be reduced to the briefest outline.

Boundary lines.—Every formation should be bordered by a definite boundary, unless transition or intergradation is meant to be shown. Except in this relatively infrequent case, it is not permissible to allow two colors or conventions to meet without an intervening boundary line. When possible, it is advisable to distinguish different grades of precision by the use of different conventional boundaries. For example, where the boundary has been traced in the field with a certain degree of precision, the separating line may be continuous; where the boundary is doubtful, or inferred, the line may be broken or dotted. Continuous lines indicating faults may be given double thickness, in order to distinguish them from continuous lines indicating precisely located boundaries,

Distinction of outcrops.—In detailed maps whose scale is sufficiently large to permit such treatment, precision is gained by distinguishing actual outcrops from areas whose geology is merely inferred. This distinction may be made by using for the outcrops either a pattern or a hachure or cross-lining under the color. The best examples of the latter method with which the writer is acquainted are to be found in Monograph XXXVI of the United States Geological Survey (*On the Crystal Falls Iron-Bearing District of Michigan*). In this volume, the practice is entirely consistent on the point in question, all its detailed geologic maps (Plates XVI, XVII, XVIII, XLIX, L, LI) distinguishing actual outcrops by means of cross-lining, disposed so as to show both location and size of these outcrops. Plate XXXI of Monograph XXXIII (*Geology of the Narragansett Basin*) distinguishes outcrops by means of cross-marks. Earlier publications on the Lake Superior region, both in monographs and in papers in the

Annual Report, have indicated actual outcrops, but the practice has not been general. It would seem that this distinction might profitably be made on maps included in the geologic folios, at least in those cases in which the geology of the area covered is complicated.

III. REQUISITE GEOGRAPHIC DATA.

Acknowledgments.—The geographic base should be credited and described, if possible, on the map itself; if the necessary description be too long for the space available, it should be contained in the textual discussion of the map. The value of a geologic map is greatly increased if the accuracy of its geography and topography can be estimated: and this is generally possible if the source whence they were derived be noted.

Scale.—Except in the case discussed in the next paragraph the scale should always be indicated diagrammatically on the map, by means of the familiar bar scale. The scale may, in addition, be indicated fractionally or verbally; allowance being made for reduction (if any) during reproduction. The shrinkage and expansion of paper due to changes in moisture are so great that these arithmetical or verbal statements of the scale are of little value; and they should never be used without a diagram.

In maps whose scale or area is so large that the effect of the earth's sphericity is appreciable, several meridians of longitude and parallels of latitude *must* be introduced and properly numbered, in order that the scale in different parts of the map be determined.

Contours.—If the base shows topography by means of contours, the datum plane and contour interval should be stated on the map.

Orientation.—When possible, the map should be so oriented with respect to the sheet on which it is printed that the north will be at the top. If this is not possible—and invariably if no parallels or meridians are introduced—the direction of a true north and south line should be indicated by the conventional arrow. In case the strike readings are quoted from the mag-

netic north, the declination of the needle should also be shown (the average for the district being taken) or stated verbally.

Projection.—In maps where scale or area is sufficiently large to render the information of value, the system of projection should be stated; or, better, it should be shown graphically by introducing a number of meridians of longitude and parallels of latitude. As noted under the discussion, in a previous paragraph, of the scale of the map, these meridians and parallels will serve a double purpose.

IV. CHOICE OF SCALE, CONVENTIONS, ETC.

Area of map and coloring.—The area covered by the map should not be larger than is necessary to illustrate the point under discussion. Whenever possible, the colors should be carried to the border of the map. Political divisions are rarely natural divisions; and it is therefore rarely advisable to stop the coloring abruptly at a political boundary, especially if the geologic value of the map can be increased by carrying the mapping into an adjoining political division.

Scale.—As the scale adopted directly affects the size of the map, the selection of the scale will frequently be affected by consideration of expense. Commonly, however, there will be room for choice, within certain limits; and in this case, or in rare instances where the question of expense may be disregarded, the selection of the scale will be subject to the following rules:

The scale should be sufficiently large to show all the geologic and geographic detail necessary. Curiously enough, this rule is rarely disregarded; the fault commonly committed being the adoption of too large a scale.

The scale should not be larger than is permitted by the degree of accuracy of the geologic field work, or by the geologic detail which must be shown. The degree of accuracy of the geologic field work will usually have been fixed by the scale of the field map on which the geologic observations were first plotted; and the published map, therefore, should not in general be on a larger scale than was this original field map.

Colors and conventions.—Whenever possible, the colors and patterns adopted by the United States Geological Survey should be adopted, for the sake of uniformity. Whether this be done or not, the maps issued by any one survey should be treated according to some one system. This is especially necessary when the maps so issued form a series, as in the publication of a number of county maps.

A formation should never be expressed by entire lack of color and pattern, as such a practice frequently leads to confusion. This, of course, refers particularly to black-and-white maps, as formations are rarely so treated on colored maps.

In small or local maps, particularly in such as are prepared for general use or to illustrate the distribution of economically important formations, the colors or conventions used for the different formations should be as distinct as possible. The smaller the areas to be distinguished, the greater will be the necessity for careful choice of colors or conventions, in order to obtain the greatest possible contrast.

In maps either of large scale, or covering large areas (in which case the geology will be of necessity much generalized), the general effect of the color scheme should be considered. In the allotment of colors and conventions to the different formations, it should be borne in mind that, the smaller the areas covered by any one formation, the brighter the color and heavier the pattern it will bear without seeming crude or obtrusive. As large maps are, in general, mounted and used as wall maps, a formation occurring mainly or entirely near the top of the map may be given a brighter color or more striking pattern than one in the middle or near the bottom of the map.

Patterns.—If patterns be used, with or without color, certain additional points must be considered. In the case of a formation occupying small areas, the pattern selected for that formation should bear some definite relation to the form and orientation of those areas. For example, a formation extended as a narrow belt should be given a pattern whose ruling is, as near as possible, at right angles to the general trend of the belt.

Experience has shown that, of the long list of patterns originally suggested for use, a certain few almost invariably fail to give good results in practice. Some of these are apparently poor, whatever paper is used; others fail only when the less highly surfaced papers are printed on. The last class are still serviceable for maps issued flat or in rolls; but can not be utilized with good results for folded maps, for which a highly surfaced paper is undesirable. Examination of a large series of maps on which patterns have been used will aid in determining which will be most effective in the special case under consideration.

In the preparation of this paper, the writer has made free use of the experience of this office, and has been greatly aided by the advice of Dr. F. J. H. Merrill. Maps issued by the United States Geological survey have been used as examples, in order to avoid the citation of maps published by the New York State Museum.

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